Rejection of claims 30-40 and 42-45 Under 35 U.S.C. §103(a)

In the May 9, 2008 Office Action, the Examiner rejected claims 30-40 and 42-45 under 35 U.S.C. §103(a) as allegedly obvious over Berger (U.S. Patent No. 6,090,799) in view of Schafer (U.S. Patent No. 4,456,596).

In response, applicant respectfully traverses the Examiner's rejection.

Different Etiologies

Examiner's Position

The Examiner has asserted that the difference in the etiologies of weight loss in Berger and Schafer, and the subjects recited in the claimed method, are inconsequential. The Examiner goes on to state, inter alia, that if it is known "that oxandrolone fosters an increase in appetite, then it reasonably follows that the administration of oxandrolone would lead to weight gain." However, the Examiner also states on page 4 of the Office Action that "calorific intake alone does not contribute exclusively to weight gain." Thus, the Examiner apparently acknowledges that simply increasing calorific intake, e.g. by increasing appetite and consumption, does not necessarily account for weight gain.

Applicant's Response

Applicant notes that the etiology of the weight loss being treated is not inconsequential. In fact, the nature of the weight loss impacts on whether a given treatment can promote weight gain in the patient suffering the weight loss.

In the present case, it is significant that the etiology of weight loss described in Berger (HIV-associated myopathy; see col. 1, lines 15-18 and 30-32) is different to that of burn-induced trauma (see page 1, lines 30-33 and page 2, lines 18-20 which describes, inter alia, weight loss due to protein and fat wasting, increased metabolic rate, and fat breakdown).

In fact, the specification describes that the metabolic rate in patients with 40% burns is 2x as high as that in patients without burns (see page 2, lines 3-5). Therefore, it would be harder for patients with at least 40% burns to gain any amount weight compared to those with the HIV-associate myopathy (as in Berger) because a burn patient is burning the metabolic energy at twice the rate. Thus, it cannot be a straightforward prediction that oxandrolone administration, which causes weight gain in a patient suffering HIV-induced myopathy, would promote any weight gain in a patient suffering weight loss resulting from a different etiology, i.e. burn-induced trauma.

Moreover, the art recognizes this concept of gain versus loss. In *Sheffield-Moore et al.* (see **Exhibit A**) where net muscle protein synthesis is measured after oxandrolone administration, the protein *breakdown* is discussed and measured as a factor in determining net change in protein synthesis (see page 2705, right hand column).

In addition, the (post-filing) reference *Sheffield-Moore et al.*, (**Exhibit A**), in pointing out the "hypercatabolic" nature of burn patients (see page 2710, right hand column, second whole paragraph), discusses *if* oxandrolone can cause a "protein synthetic response" that is "sufficient to ameliorate

the net amino acid efflux and protein catabolism" associated with, in that experimental case, an overnight fast. Thus, the relationship between weight loss (through the etiology of the condition causing weight loss) and an actual weight gain caused by oxandrolone is not predictable merely on the basis of oxandrolone fostering "an increase in appetite."

Moreover, *Sheffield-Moore et al.*, goes on to state in relation to (*inter alia*) burn patients, that "[h]owever, the time period needed for protein accretion to occur in these patient groups is not known." Thus, the post-filing art indicates that it is not predictable whether the protein synthetic response caused by oxandrolone would be sufficient to ameliorate net amino acid efflux and protein catabolism. Accordingly, based on the cited combination of prior art, at the time of filing it was not predictable that administration of oxandrolone would result in weight gain in a patient suffering weight loss resulting from burn-induced trauma.

<u>Weight Gain</u>

Applicants specifically note that, in light of comments made by the same Examiner in an Office Action issued October 17, 2008 in related United State Serial No. 10/799,284, although the etiology of a weight loss does not "alter the functionality of oxandrolone", as stated by the Examiner, it is not predictable that oxandrolone simply "fostering" an increase in appetite can cause weight gain. The reason for this is there can only be weight <u>gain</u> if the amount of weight added <u>exceeds</u> the amount of weight being <u>lost</u>. As the art makes it clear it is <u>not predicable</u> if this situation will be the case, especially in burns patients where the metabolic

rate is so high. Regardless of whether the "functionality" of oxandrolone is changed by etiology, it does not predictably follow that oxandrolone administration will cause weight gain. The Examiner appears to assert that such a situation will merely affect the "quantity and/or rate of weight gain," when in fact it will bear on whether there is any weight gain.

To be clear as to the claimed effect of causing weight gain, applicants note that as set forth in the specification, the administration of oxandrolone to the "Group 3" burn victim patients resulted in a weight gain of four times that seen in the control "Group 1" burn victim patients (see specification, p. 15, lines 19 and 20). Also, as the specification states at p. 15, lines 23-25, "[t]he combination of Met-RX™ and oxandrolone results in a great weight gain considered to be 80% lean body weight gain by biolelective impedance measurements." Accordingly, it is clear that oxandrolone administration in these patients resulted in actual weight gain. Given the acknowledged increased metabolism in burn victims, whether increasing appetite would cause an actual weight gain, or simply a decrease in the rate of loss of weight, was not predictable based on the prior art.

Accordingly, applicant respectfully requests reconsideration and withdrawal of this ground of rejection.

Rejection of claims 30 and 41 Under 35 U.S.C. §103(a)

The Examiner also rejected claims 30 and 41 under 35 U.S.C. §103(a) as allegedly obvious over Berger, as cited, in view of Schafer, as cited, and in further view of Labrie et al. (U.S. Patent No. 5,434,146). The Examiner also stated, inter alia,

that the arguments supplied in the Office Actions of March 23, 2007 was incorporated by reference. Briefly, the arguments previously set forth by the Examiner are that Berger does not teach the administration of oxandrolone in a sustained release formulation but that Labrie et al. teach the administration of oxandrolone in a sustained release formulation. The Examiner alleged that in view of this it would have been prima facie obvious to one of ordinary skill in the art that the administration of an effective amount of oxandrolone in a sustained release formulation would be effective for promoting weight gain after weight loss resulting from burn-induced trauma. The Examiner further stated that applicant argued that neither Berger nor Labrie et al. teach a sustained release formulation for oxandrolone. The Examiner asserted, however, that Labrie et al. do teach the sustained release of oxandrolone, citing Abstract, col. 21, lines 17 and 61-68 and col. 23, lines 20-24).

Applicant notes that, as set forth hereinabove, there is no teaching of the method of claim 30 in the combination of Berger and Schafer. Applicant further notes that Labrie et al. in combination with the other cited art does not cure this deficiency, nor does the Examiner suggest that it does. Applicant maintains that the cited combined references do not teach or make obvious applicant's invention as claimed.

Applicant maintains that claims 30-47 are not obvious over the combination of cited references. Accordingly, applicant respectfully requests that the Examiner reconsider and withdraw this ground of rejection.

If a telephone interview would be of assistance in advancing

prosecution of the subject application, applicant's undersigned attorney invites the Examiner to telephone him at the number provided below.

No fee, apart from the total enclosed fee of $555.00 for the three-month extension of time, is deemed necessary in connection with the filing of this Communication. However, if any additional fee is required, authorization is hereby given to charge the amount of any such fee to Deposit Account No. 03-3125.

Respectfully submitted,

Gary J. Gershik

John P. White
Registration No. 28,678
Gary J. Gershik
Registration No. 39,992
Attorneys for Applicant
Cooper & Dunham LLP
1185 Avenue of the Americas
New York, New York 10036
(212) 278-0400

I hereby certify that this correspondence is being deposited this date with the U.S. Postal Service with sufficient postage as first class mail in an envelope addressed to:

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Gary J. Gershik 11/10/08
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Reg. No. 28,678
Gary J. Gershik
Reg. No. 39,992

EXHIBIT A

Response to May 9, 2008 Office Action

Applicant: Don Fishbein
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Short-Term Oxandrolone Administration Stimulates Net Muscle Protein Synthesis in Young Men*

MELINDA SHEFFIELD-MOORE, RANDALL J. URBAN, STEVEN E. WOLF, J. JIANG, DON H. CATLIN, DAVID N. HERNDON, ROBERT R. WOLFE, AND ARNY A. FERRANDO

Departments of Surgery (M.S.-M., S.E.W., D.N.H., R.R.W., A.A.F.), Anesthesiology (R.R.W.), and Internal Medicine (R.J.U., J.J.), University of Texas Medical Branch, and Shriners Burn Hospital for Children (D.N.H., R.R.W.), Galveston, Texas 77550; and the Department of Molecular and Medical Pharmacology, University of California, Olympic Analytical Laboratory (D.H.C.), Los Angeles, California 90025

ABSTRACT

Short term administration of testosterone stimulates net protein synthesis in healthy men. We investigated whether oxandrolone [Oxandrin (OX)], a synthetic analog of testosterone, would improve net muscle protein synthesis and transport of amino acids across the leg. Six healthy men [22 ± 1 (±SE) yr] were studied in the postabsorptive state before and after 5 days of oral OX (15 mg/day). Muscle protein synthesis and breakdown were determined by a three-compartment model using stable isotopic data obtained from femoral arterio-venous sampling and muscle biopsy. The precursor-product method was used to determine muscle protein fractional synthetic rates. Fractional breakdown rates were also directly calculated. Total messenger ribonucleic acid (mRNA) concentrations of skeletal muscle insulin-like growth factor I and androgen receptor (AR) were determined using RT-PCR. Model-derived muscle protein synthesis increased from 53.5 ± 3 to 68.3 ± 5 (mean ± SE) nmol/min·100 mL/leg ($P < 0.05$), whereas protein breakdown was unchanged. Inward transport of amino acids remained unchanged with OX, whereas outward transport decreased ($P < 0.05$). The fractional synthetic rate increased 44% ($P < 0.05$) after OX administration, with no change in fractional breakdown rate. Therefore, the net balance between synthesis and breakdown became more positive with both methodologies ($P < 0.05$) and was not different from zero. Further, RT-PCR showed that OX administration significantly increased mRNA concentrations of skeletal muscle AR without changing insulin-like growth factor I mRNA concentrations. We conclude that short term OX administration stimulated an increase in skeletal muscle protein synthesis and improved intracellular reutilization of amino acids. The mechanism for this stimulation may be related to an OX-induced increase in AR expression in skeletal muscle. (*J Clin Endocrinol Metab* **84:** 2705–2711, 1999)

ATHLETES have long used anabolic agents for improving lean muscle mass and strength. However, clinicians have only recently recognized the benefits of anabolic agents for patients with trauma- and disease-related muscle wasting. Recently, several clinical studies demonstrated the positive benefits of testosterone (T) administration to various patient populations. In particular, hypogonadal men benefit from T replacement therapy via enhanced skeletal muscle mass (1–3), increased bone density (2), and increased protein synthesis (1). Likewise, elderly men receiving T replacement therapy have increased lean body mass (4), strength (5), and protein synthesis (5) along with decreased bone resorption (4). Moreover, changes in body composition, including a loss in lean body mass, are highly correlated with androgen levels in hypogonadal men with the acquired immunodeficiency syndrome (AIDS) wasting myopathy (6).

We recently showed that T enanthate (TE), administered im to healthy young men, increased net protein synthesis and reutilization of intracellular amino acids in skeletal muscle (7). In addition, several other studies have found T administration to increase muscle protein synthesis (1, 5, 8), although these studies failed to measure protein breakdown. One of the major limitations of previous studies of fractional synthetic rate (FSR) is that no estimation of protein breakdown could be made simultaneously. Consequently, the traditional approach to the study of muscle protein kinetics (*i.e.* FSR) provided no information on the net balance between synthesis and breakdown. Therefore, our laboratory developed a new method for measuring fractional protein breakdown that is independent of the arterio-venous (A-V) model (9).

Although natural androgens such as T clearly stimulate muscle protein synthesis, they also possess androgenic or virilizing effects. Often this limits the clinician's use of these androgens to specific patient populations such as hypogonadal men. However, efforts have been made to find alternative anabolic agents that can be used in women and children suffering from muscle-wasting diseases or trauma. Oxandrolone [Oxandrin (OX) Bio-Technology General, Iselin, NJ], a synthetic analog of T, is an oral anabolic steroid currently used as an adjunctive therapy to promote weight gain in patients after surgery, chronic infections, and severe trauma. OX improved weight gain in patients experiencing AIDS-wasting myopathy (10) as well as in convalescing burn

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Address all correspondence and requests for reprints to: Melinda Sheffield-Moore, Ph.D., Metabolism Unit, Shriners Burns Institute, 815 Market Street, Galveston, Texas 77550. E-mail: melmoore@utmb.edu.

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Applicants: Don Fishbein
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Exhibit A

patients (30–50% total body surface area burns) (11). In addition, OX is used by clinicians to treat children with growth disorders such as Turner's syndrome and constitutional delay of growth and puberty (12, 13). A recent pilot study in boys with Duchenne muscular dystrophy found that OX, given at a dose of 0.1 mg/kg·day, improved muscle strength over a 3-month period (14). Given that OX is administered orally, as opposed to im as with TE, its ease of administration makes it attractive to clinicians and patients alike. Further, OX is purported to have a much greater anabolic potential than T, with fewer of the androgenic effects. However, no studies have demonstrated whether OX, similar to TE, promotes the stimulation of protein synthesis in skeletal muscle.

Hence, we investigated whether OX, a purported anabolic agent, improves net muscle protein synthesis and transport of amino acids in fasted young men. The present study was designed to mimic the 5-day TE study in normal males previously discussed (7). We sought to evaluate the short term (5-day) effects a moderate dose (15 mg/day) of OX on the incorporation of amino acids into muscle proteins using an established protein kinetic model (15, 16). We further examined the effect of OX on the messenger ribonucleic acid (mRNA) concentrations of skeletal muscle insulin-like growth factor I (IGF-I) and androgen receptors (AR).

Subjects and Methods

Subjects

Six healthy men [age, 22 ± 3 (±SD) yr; weight, 77 ± 13 kg; height, 178 ± 7 cm] were studied before and after taking a daily dose of oral OX (15 mg/day) for 5 days. All subjects gave informed written consent according to the guidelines established by the institutional review board at the University of Texas Medical Branch (Galveston, TX). Subject eligibility was assessed by performing a medical screening, which included an electrocardiogram, blood count, plasma electrolytes, blood glucose concentration, and liver and renal function tests. Subjects presenting with heart or liver disease, hypo- or hypercoagulation disorders, vascular diseases, hypertension, diabetes, or an allergy to iodides were excluded from participation.

Experimental protocol

All isotope infusion studies were performed at the General Clinical Research Center at the University of Texas Medical Branch. Subjects were admitted the night before each study and were fasted from 2200 h until completion of the 5-h isotope infusion study. At approximately 0630 h the following morning (day 0), a 20-gauge polyethylene catheter (Insyte-W, Becton Dickinson and Co., Sandy, UT) was inserted into the antecubital vein of one arm for the infusion of amino acids. A second 20-gauge polyethylene catheter was placed in the contralateral wrist for blood sampling for measurement of systemic indocyanine green (ICG). A heating pad was placed around the arm and wrist to maintain a temperature of about 65 C during blood flow measurements.

At 0700 h on days 0 and 5, baseline blood samples were drawn for the analysis of background amino acid enrichment, ICG concentration, and peak T and OX concentrations. A primed continuous infusion of labeled phenylalanine was initiated at the following infusion rate (IR) and priming dose (PD): L-[ring-$^{2}H_{5}$]phenylalanine, IR = 0.05 μmol/kg·min, PD = 2 μmol/kg. At approximately 0730 h, a 3-Fr 8-cm polyethylene Cook catheter (Bloomington, IN) was placed under local anesthesia into the femoral artery and vein. Femoral catheters were required for A-V blood sampling and infusion of ICG (artery) for determination of leg blood flow.

Biopsies of the vastus lateralis were obtained at 2 h, 4 h 30 min, and 5 h of tracer infusion using a 5-mm Bergström needle as previously described (16). Tissue was immediately frozen in liquid nitrogen and stored at −80 C until analysis. After the 2-h biopsy, a primed (2 μmol/kg) continuous infusion of L-[^{15}N]phenylalanine was initiated and maintained until 4 h (Fig. 1). Arterial and intracellular L-[^{15}N]phenylalanine enrichments at plateau and again after decay were obtained for purposes of determining the fractional breakdown rate (FBR). The 4 h 30 min and 5 h biopsies were used to determine FBR. The fractional synthetic rate (FSR) of skeletal muscle protein was determined by the incorporation of L-[ring-$^{2}H_{5}$]phenylalanine into protein from 2–5 h.

A-V blood samples were obtained at 20-min intervals from 4–5 h to determine amino acid kinetics. Fifteen minutes before the sampling hour, a continuous infusion (IR = 0.5 mg/min) of ICG was initiated and allowed to reach systemic equilibrium (10–15 min) for purposes of measuring leg blood flow. Subsequent blood sampling was performed simultaneously from the femoral vein and heated wrist vein throughout the sampling hour. To avoid disrupting blood flow measurements, all A-V blood samples for amino acid kinetics were obtained after taking the blood flow measures, and the ICG was stopped. ICG was restarted and allowed to run uninterrupted for approximately 10–15 min before the next blood flow measurement.

At the end of the 5-h infusion study, subjects were fed, and all peripheral and femoral catheters were removed. Beginning at 2100 h on day 0, all subjects were given 15 mg OX (BTG Pharmaceuticals Co., Iselin, NJ), orally, for 5 days. On day 3, subjects returned to the General Clinical Research Center at 0700 h for venous blood sampling to determine total T and OX concentrations. On day 5, the above experimental protocol was repeated.

Analytical methods

Blood. The concentrations of unlabeled and labeled phenylalanine were determined by gas chromatography-mass spectrometry (GC-MS) as previously described (16). Briefly, A-V blood samples were collected in preweighed tubes containing 15% sulfosalicylic acid. A known internal standard (100 μL/mL blood) was added and thoroughly mixed. The composition of this standard mixture was 50.3 μmol/L L-[ring-$^{13}C_{6}$]phenylalanine. After reweighing the tubes to determine the final blood volume, tubes were centrifuged, and the supernatant was collected and stored at −20 C until analysis. Blood amino acids were separated using cation exchange chromatography (16) and enrichments of the internal standard, and infused tracers were determined on their *tert*-butyldimethylsilyl (*t*-BDMS) derivatives (17). Using the GC-MS, the isotopic enrichment of free amino acids in blood was determined by positive chemical ionization and selected ion monitoring (model 5973, Hewlett-Packard Co., Palo Alto, CA). Finally, leg blood flow was determined spectrophotometrically by measuring serum ICG concentration at λ = 805 nm.

Muscle. Muscle samples were weighed, and protein was precipitated with 500 μL 14% perchloric acid. A known internal standard solution (2 μL/mg muscle tissue) was added to measure the intracellular concentrations of phenylalanine. The solution contained 2.4 μmol/L L-[ring-$^{13}C_{6}$]phenylalanine. The supernatant was collected after homogenization of the tissue and centrifugation. This procedure was repeated three times. The pooled supernatant with muscle amino acids was separated

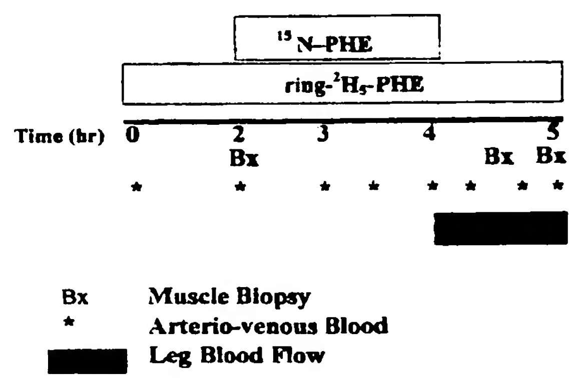

FIG. 1. Stable isotope infusion protocol. ring-$^{2}H_{5}$-PHE, L-[ring-$^{2}H_{5}$]phenylalanine; ^{15}N-PHE, L-[^{15}N]phenylalanine.

using cation exchange chromatography (16). Intracellular amino acid enrichments and concentrations were determined on their *tert*-butyl-methylsilyl derivatives (17) using GC-MS in the electron impact mode. Intracellular enrichment was determined by correction for extracellular fluid based on the chloride method (18). The remaining pellet was washed several times with 0.9% saline and again with absolute ethanol, dried at 50 C overnight, and hydrolyzed in 6 N HCl at 110 C for 24 h. The hydrolysate was then passed over a cation exchange column in the same manner as the blood was processed. Samples were analyzed for phenylalanine enrichment by GC-MS (model 8000, MD 800, Fisons Instruments, Manchester, UK) using chemical ionization and the standard curve approach (19).

Hormone assays. The concentration of total T was measured in serum with a commercial RIA kit (Diagnostic Products, Los Angeles, CA). Free or bioavailable T was measured by equilibrium dialysis [Mayo Medical Laboratories (Rochester, MN), Quest Diagnostics, Inc., Nichols Institute (San Juan Capistrano, CA)]. Serum OX concentrations were measured by University of California-Los Angeles Olympic Analytical Laboratory. Briefly, a liquid-liquid extraction was performed by adding 50 μL internal standard [16,16,17-^{3}H]T (d^3T; 12 μg/mL; MSD Isotopes, Montreal, Que.), 1 mL 50% saturated sodium acetate buffer (0.5 mol/L; pH 5.5), and ethyl ether (5 mL) to 0.5 mL plasma. After vortexing (10 min) and centrifugation (15 min at 2000 rpm), the ethyl ether layer was dried under nitrogen at room temperature and reconstituted in 200 μL methanol for high performance liquid chromatography analysis. Liquid chromatography was performed on a Shimadzu system (Shimadzu, Columbia, MD) equipped with a Hypersil BDS C_{18}, 50 × 2-mm column (Keystone Scientific, Inc., Bellefonte, PA) and Hypersil BDS C_{18}, 20 × 2-mm precolumn, operated at a flow rate of 400 μL/min. The injection volume was 5 μL. The gradient was methanol-water (1:1) for 1 min, methanol-water (9:1) for the next 1 min, a 1-min hold, and a return to the starting condition in 0.5 min. MS analyses were performed on a triple quadrupole Perkin Elmer Corp.-Sciex API 300 (Norwalk, CT) equipped with an APCI interface. The nebulizer temperature was optimized for maximum sensitivity at 350 C. Positive ions (m−1) for OX (307.2; Searle Pharmaceutical, Chicago, IL) and d^3T (292.2) were admitted into the second quadrupole for collision-induced dissociation. Product ions 289.2 and 97.0 were monitored and used to quantitate OX and d^3T, respectively. Concentrations were determined by reference to a six-point calibration curve.

Total RNA isolation and qualitative RT-PCR. Total RNA was isolated from muscle biopsy samples (50–75 mg) using RNAzol B (Tel-Test, Inc., Friendswood, TX). Two micrograms of total RNA were then converted to DNA using a Reverse Transcription System (Promega Corp., Madison, WI). The DNA (5 μL) was then subjected to PCR in the presence of the appropriate primers. The products of the PCR were run on Southern gel, and amplified DNA products were sized by DNA ladder. Southern blots were then made and hybridized to oligonucleotides of the DNA fragment. Glyceraldehyde phosphate dehydrogenase (GAP) was coamplified in each sample as an internal control. For the AR, the downstream primer was included in the reverse transcriptase reaction. The primers and hybridization oligonucleotides for the IGF-I and AR are as follows: IGF-I: sense, 5′-AAATCAGCAGTCTTGGAACC-3′; antisense, 5′ CTTCTGGCGTCTTGGGCATGT 3′; oligonucleotide, 5′-CAAGCCCACAGGGTATGGCTCCAGCAGT-3′; AR: sense, 5′-GATGCTCTACTTCGCCCCTGA-3′; antisense, 5′-CCCAGCAAATAGAATTCCATGAC-3′; oligonucleotide, 5′-CTGGGTGTGGAAATAGATG-3′; and GAP: sense, 5′-GGTATCGTGGAAGGACTCAT-3′; antisense, 5′-TCCACCACCCTGTTGCTGTA-3′; oligonucleotide, 5′-GTGGGTGTCGCTGTTGAAGT-3′.

Southern blot band densities were measured using the ImageQuant analysis program (Molecular Dynamics, Inc., Sunnyvale, CA).

Calculations

Kinetic model. The kinetics of intracellular free amino acids have been described previously (16). However, we will briefly detail the kinetic parameters that make up the three-pool model of leg amino acid kinetics (Fig. 2).

The femoral artery delivers (F_{in}) amino acids to the leg, whereas amino acids leave via the femoral vein (F_{out}). These amino acids can, therefore, move intercompartmentally between the artery (A), vein (V), and muscle (M). Inward amino acid transport from A to M ($F_{M,A}$) and outward amino transport from M to V ($F_{V,M}$) occur via the femoral artery and vein, respectively. Thus, inward (F_{in}) and outward (F_{out}) tissue transport were calculated as follows:

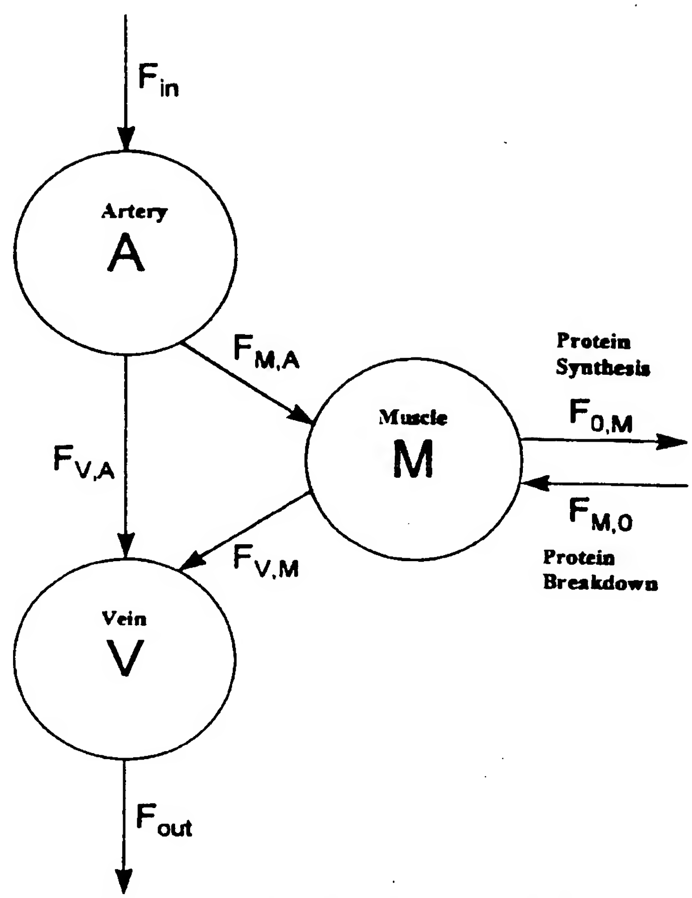

FIG. 2. Three-compartmental model of leg amino acid kinetics. Free amino acid pools in femoral artery (A), femoral vein (V), and muscle (M) are connected by *arrows*, indicating unidirectional amino acid flow between each compartment. Amino acids enter the leg via femoral artery (F_{in}) and leave via femoral vein (F_{out}). $F_{V,A}$ is the direct flow from artery to vein of the amino acids that do not enter the intracellular fluid. $F_{M,A}$ and $F_{V,M}$ are the inward and outward transport from the artery to the muscle and from the muscle to the vein, respectively. $F_{M,O}$ is the intracellular amino acid appearance from proteolysis for phenylalanine. $F_{O,M}$ is the rate of disappearance of intracellular amino acids for protein synthesis for phenylalanine.

$$F_{in} = C_A \times BF \tag{I}$$

$$F_{out} = C_V \times BF \tag{II}$$

$$F_{M,A} = \{[(E_M - E_V)/(E_A - E_M)] \times C_V + C_A\} \times BF \tag{III}$$

$$F_{V,M} = \{[(E_M - E_V)/(E_A - E_M)] \times C_V + C_V\} \times BF \tag{IV}$$

where C_A and C_V, and E_A and E_V are amino acid concentrations and tracer enrichments in the femoral artery and vein, and E_M is enrichment in the muscle. Leg blood flow is represented by BF. Amino acids that bypass the muscle via the femoral artery can be calculated by either of the following expressions:

$$F_{V,A} = F_{in} - F_{M,A} \quad (V)$$

$$F_{V,A} = F_{out} - F_{V,M} \quad (VI)$$

The model also enables the calculation of the rate of intracellular appearance ($F_{M,O}$) of amino acids from protein breakdown and the rate of amino acid utilization ($F_{O,M}$) for protein synthesis. Amino acid appearance and utilization are calculated by the following formulas, respectively:

$$F_{M,O} = F_{M,A} \times (E_A/E_M - 1) \quad (VII)$$

$$F_{O,M} = (C_A \times E_A - C_V \times E_V) \times BF/E_M \quad (VIII)$$

The following expression represents the total rate of appearance (Ra_M) of the intracellular amino acids, which is a function of protein breakdown ($F_{M,O}$) and inward tissue transport ($F_{M,A}$).

$$Ra_M = F_{M,O} + F_{M,A} \quad (IX)$$

Protein synthesis efficiency (PSE). Using phenylalanine, we calculated the relative efficiency of protein synthesis as follows:

$$PSE = F_{O,M}/(F_{M,A} + F_{M,O}) \quad (X)$$

PSE is defined as the fraction of the intracellular amino acid rate of appearance that is incorporated into muscle proteins, taking into account that phenylalanine is not oxidized in the muscle. Therefore, $F_{O,M}$ represents the amount of amino acid incorporated in the muscle proteins.

FSR. Using the traditional precursor-product method, we determined the FSR of muscle proteins by measuring the rate of phenylalanine tracer incorporation into protein and the enrichment of the intracellular pool as the precursor

$$FSR = [(E_{p2} - E_{p1})/(E_M \times t)] \times 60 \times 100 \quad (XI)$$

where E_{p1} and E_{p2} are the enrichments of the protein-bound L-[*ring*-$^2H_5$]phenylalanine at the 2 and 5 h sampling points. Average intracellular L-[ring-$^2H_5$]phenylalanine enrichment is E_M, whereas time in minutes is represented by t. To express FSR as a percentage per h, the expression is then multiplied by the factors 60 (minutes per h) and 100, respectively.

FBR. We will briefly discuss the new method for measuring fractional protein breakdown, which has been derived and described in detail previously (9). Further, the FBR method has recently been validated in a report from this laboratory (20). This method employs a variation of the traditional precursor-product method for determining FSR. In this case, the product is free intracellular amino acids, and the precursors are arterial blood and tissue protein.

The FBR technique involves stopping enrichment after reaching an isotopic equilibrium of L-[^{15}N]phenylalanine and determining the rate of decay of the intracellular amino acid enrichment. The rate of decay of the free intracellular enrichment is determined by the arterial decay (which continues to provide a certain amount of label to the intracellular pool as well as unlabeled amino acids) and the FBR (which provides the rest of the unlabeled amino acids). Because FBR is constant at physiological steady state, and the decay curves in the arterial and intracellular pools are measurable, FBR is measurable. The following equation is used for the calculation of FBR:

$$FBR = \frac{E_F(t_2) - E_F(t_1)}{P\int_{t_1}^{t_2} E_A(t)dt - (1 + p)\int_{t_1}^{t_2} E_F(t)dt} \times \frac{T}{Q_F} \quad (XII)$$

where $P = E_F/(E_A - E_F)$ at isotope plateau, $E_A(t)$ and $E_F(t)$ are the arterial and intracellular enrichments, and T/Q_F is the ratio of bound to unbound amino acid in the tissue sample.

Without the variables P and T/Q_F in the above equation, the equation is simply the traditional precursor-product equation. The traditional precursor-product equation assumes that the product is only derived from one precursor. However, when determining FBR, the product has two sources, plasma amino acids and protein-bound amino acids. These two sources are therefore represented by the variable P. P is equal to the ratio of protein breakdown to transport of amino acids into the cell and is calculated by determining the dilution of amino acid enrichment between plasma and the intracellular space at isotopic steady state.

The factor T/Q_F is necessary to make the units of FBR comparable to those of FSR, such that the units of FBR are rate of protein breakdown divided by the bound amino acid pool size. The traditional precursor-product equation calculates the rate of conversion of precursor to product divided by the product pool size. However, with FBR, the rate of protein breakdown is divided by the free intracellular amino acid pool size. Finally, in this FBR model, as well as in the kinetic determination of the rate of appearance from protein breakdown ($F_{M,O}$) and disappearance to protein synthesis ($F_{O,M}$), an assumption must be made that the label is not recycled from protein breakdown back to the free intracellular pool. This is reasonable, given the low enrichment of the muscle pool, compared to the free intracellular enrichment at isotopic equilibrium. This leaves arterial blood as the only source of tracer for the free intracellular pool. In contrast, unlabeled amino acids from both arterial blood and protein breakdown contribute to the free intracellular pool.

Statistical analysis. Comparisons between basal and treatment conditions were performed using paired t tests. Statistical significance was established at $P \leq 0.05$. Data are presented as the mean ± SE.

Results

As depicted in Table 1, arterial steady state was achieved during the sampling hour (240–300 min) of both the control period and after 5 days of OX administration. However, arterial enrichments were significantly higher after OX treatment (Table 1; $P < 0.05$). Due to noncompliance with medications by one subject, all data presented include only the results from five subjects.

Serum OX concentrations on day 3 (1.9 ± 0.4 ng/dL) and day 5 (2.2 ± 0.3 ng/dL) of OX administration, measured 10 h after each evening's oral dose (2100 h), remained steady. However, by 18 h posttreatment on day 5, serum OX levels were markedly reduced (0.48 ± 0.06 ng/dL; $P < 0.01$) compared to day 3 or day 5 10-h values. Total serum T concentrations were within normal physiological range on day 0 (449 ± 35 ng/dL) and day 3 (441 ± 44 ng/dL) of OX treatment. However, by day 5, total serum T concentrations were significantly reduced (282 ± 45 ng/dL; $P < 0.05$) below day 0 and day 3 values (Fig. 3). Serum free T concentrations were within normal physiological range on days 0, 3, and 5. However, by day 5, serum free T concentrations were significantly reduced (98 ± 10 pg/mL; $P < 0.001$) below day 0 (121 ± 12 pg/mL) and day 3 (126 ± 9 pg/mL) values. Hence, the total androgen concentration (T + OX) was reduced in parallel to the reduction in T (Fig. 3).

FSR increased from 0.057 ± 0.004% to 0.082 ± 0.008%/h after 5 days of OX administration (Fig. 4; $P < 0.05$), whereas FBR remained unchanged (0.138 ± 0.005% *vs.* 0.118 ± 0.0008%/h; $P = 0.40$). Whole body appearance of phenylalanine decreased from 0.80 ± 0.03 to 0.75 ± 0.03 μmol/kg·min after OX treatment ($P < 0.05$).

The model-derived parameters of leg muscle free amino acid kinetics of the five subjects in the control period and after 5 days of OX are shown in Table 2. OX treatment had no effect on amino acid delivery to (F_{in}) or the release of labeled phenylalanine from the leg (F_{out}). Moreover, the inward transport rate ($F_{M,A}$) of phenylalanine remained unchanged. However, 5 days of OX administration resulted in a significant reduction in the rate of outward

TABLE 1. Femoral artery free amino acid enrichments

Min of infusion	Phenylalanine	
	Control (tracer/tracee)	Oxandrolone (tracer/tracee)
240	0.0646 ± 0.0035	0.0759 ± 0.0032[a]
260	0.0640 ± 0.0030	0.0722 ± 0.0016[a]
280	0.0647 ± 0.0038	0.0672 ± 0.0025[a]
300	0.0638 ± 0.0017	0.0715 ± 0.0022[a]

Data are the mean ± SE and are expressed as the tracer to tracee ratio. All tracer values during control and oxandrolone infusions are at steady state across infusion time by ANOVA. Samples from 240–300 min of isotope infusion were used for model calculations. Mean tracer to tracee ratios are significantly greater after 5 days of oxandrolone administration by paired t test.

[a] $P < 0.05$.

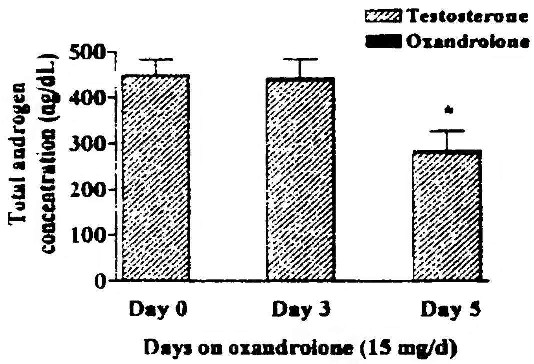

FIG. 3. Total androgen concentration. Total serum T (*hatched portion*) and OX (*black portion*) concentrations in five young men on days 0, 3, and 5. *, T decreased significantly from days 0 and 3 to day 5 ($P < 0.05$).

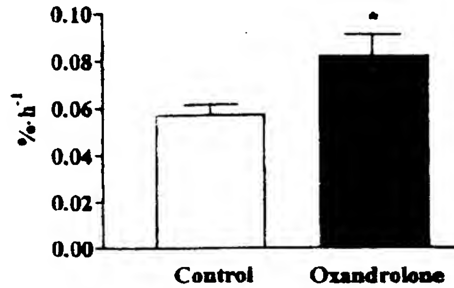

FIG. 4. Muscle protein FSR. Muscle protein FSR in five young men during the postabsorptive state both before (control, *open bar*) and after (OX, *black bar*) OX administration. *, Five days of OX administration increased the synthesis rate of muscle proteins by approximately 44% ($P < 0.05$).

TABLE 2. Effect of oxandrolone treatment on leg muscle free amino acid kinetics in young men

Kinetic parameter	Phenylalanine	
	Control	Oxandrolone
F_{in} (arterial delivery)	263 ± 46	227 ± 42
F_{out} (venous outflow)	293 ± 46	228 ± 45
$F_{M,A}$ (inward transport)	144 ± 17	124 ± 25
$F_{V,M}$ (outward transport)	175 ± 15	125 ± 29[a]
$F_{V,A}$ (functional shunting)	118 ± 35	102 ± 17
$F_{M,O}$ (protein breakdown)	83 ± 8	69 ± 8
$F_{O,M}$ (protein synthesis)	53 ± 3	68 ± 5[a]
Ra_M (intracellular appearance)	228 ± 16	193 ± 32
NB (net balance)	−30 ± 6	−1 ± 4[a]

Data are the mean ± SE and are expressed as nanomoles per min/100 mL leg.

[a] Significantly different after 5 days of oxandrolone administration, $P < 0.05$.

transport of phenylalanine ($F_{V,M}$; $P < 0.05$). The intracellular rate of appearance of phenylalanine ($F_{M,O}$), an index of proteolysis, did not change after OX administration (Table 2). However, consistent with the direct incorporation data, the rate of intracellular utilization of phenylalanine for protein synthesis ($F_{O,M}$) increased significantly after OX treatment (Table 2; $P < 0.05$). As a result of the increase in $F_{O,M}$ and the lack of change in $F_{M,O}$, net balance (NB) shifted from a net negative output (−30 ± 6) during the fasted control period to an approximate zero balance (−1 ± 4) during an overnight fast after 5 days of OX (Table 2; $P < 0.05$). Protein synthesis efficiency increased significantly from control to OX periods (24 ± 0.03% *vs.* 39 ± 0.07%; $P < 0.05$). Finally, OX had no effect on leg blood flow.

OX administration significantly increased mRNA concentrations of skeletal muscle AR without changing IGF-I mRNA concentrations. Figure 5 shows a representative autoradiogram of a Southern blot hybridization for skeletal muscle AR and a graph of the densitometry data from all five subjects. IGF-I mRNA concentrations were not significantly increased after 5 days of OX treatment (control, 2.3 ± 0.6; OX, 3.1 ± 0.5). GAP concentration did not change. The data are presented as a ratio of the AR band density over the GAP band density.

Discussion

We examined the response of muscle protein kinetics to OX administration in normal young men. We demonstrated that a moderate dose of OX, given over 5 days, stimulated muscle protein anabolism in young men. Further, we demonstrated for the first time in humans an increase in skeletal muscle ARs after anabolic intervention. Muscle anabolism during OX treatment occurred by stimulation of protein synthesis, as protein breakdown was unchanged. Moreover, a significant decrease in model-derived outward transport ($F_{V,M}$) along with the calculated increase in protein synthetic efficiency indicate increased intracellular reutilization of amino acids. Taken together, these results demonstrate the mechanism of OX's anabolic properties in fasted skeletal muscle.

A recent study from our laboratory (7) demonstrated that 5 days after a single im injection of TE (200 mg), FSR and model-derived protein synthesis increased 2-fold, with no change in FBR. Further, in agreement with the present findings, Ferrando *et al.* (7) demonstrated an increased utilization of intracellular amino acids by showing a strong relationship between protein breakdown and protein synthesis. Although our kinetic data strongly support these findings, the magnitude of the synthetic response with OX was not as great as that with TE. With OX, we found 44% and 28% increases in FSR and model-derived protein synthesis ($F_{O,M}$), respec-

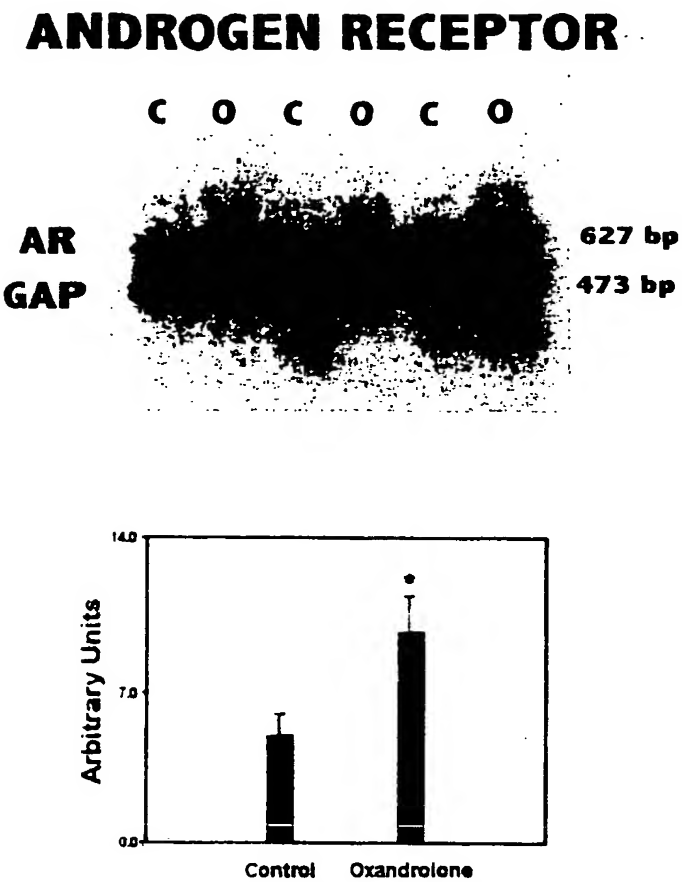

FIG. 5. AR mRNA concentrations. *Top*, Representative autoradiogram of a Southern blot hybridization of RT-PCR product from the total RNA of muscle biopsies from three subjects who were treated with OX (15 mg/day for 5 days). GAP was used as an internal control. C, Control; O, OX. *Bottom*, Graph of the mean ± SE from all five subjects. The data are expressed as arbitrary units calculated as the ratio of the band densities of AR over the band densities of GAP (internal control). Statistical significance was determined by paired *t* test (*, $P \leq 0.05$).

tively. Several important factors may account for these differences.

In our previous study, the total T concentration increased to twice the physiological norm 2 days after TE injection (2094 ± 561 ng/dL). Further, T was still in the upper physiological range (953 ± 283 ng/dL) by day 5 and was statistically different from preinjection T concentration (425 ± 99 ng/dL) (7). In contrast, the magnitude of response we found in serum OX concentration was much less than that reported with TE. For example, total serum OX, as measured in the morning 10 h after oral ingestion, was consistent on days 3 and 5, whereas total serum and free T concentrations declined significantly from days 0 and 3 to day 5. Viewed in combination, total serum androgen levels with OX treatment were far below those obtained with TE. Although the total androgen exposure to the skeletal muscle with OX may have been considerably less than that we found previously with TE, an increase in protein synthesis was nonetheless observed. This suggests that OX may exert a greater anabolic influence on skeletal muscle than TE, thereby overcoming the decrease in the T concentration.

Further evidence indicates that the method of administration and metabolism of the anabolic agent may account for the magnitude of difference in protein synthesis with OX compared to TE. For example, im TE injections are administered in a lipid base such that they can be stored in adipose tissue and released slowly, giving a sustained duration of action. After im injection of 200 mg TE, serum T levels rise and can reach the supraphysiological range within 24 h of administration. Over a period of several weeks, these levels gradually decline to hypogonadal levels (21). In the present study, serum OX levels on day 5 were 2.19 ng/dL 10 h after oral administration. However, by 18 h, serum OX levels fell to 0.48 ng/dL, representing a 78% reduction in serum OX in only 8 h. Because of this rapid decline in OX blood levels, it may be warranted to administer OX twice a day to maintain higher sustained blood levels of total androgen, possibly further enhancing its anabolic effect on skeletal muscle.

Moreover, OX's potent protein synthetic response was sufficient to ameliorate the net amino acid efflux and protein catabolism associated with an overnight fast. Given that most trauma and burn patients are acutely hypercatabolic, and most cancer and AIDS patients are chronically catabolic, the ability to reverse the inevitable losses in lean body mass using an oral anabolic agent has considerable clinical implications. However, the timeframe needed for protein accretion to occur in these patient groups is not known. At a minimum, efficient reutilization of intracellular amino acids is necessary for continued maintenance of the metabolic state (7, 22). We know that during the fasted state, protein breakdown is normally much higher than protein synthesis (16, 22). Despite being fasted overnight, all subjects had an increased reutilization of amino acids as outward transport ($F_{V,M}$) decreased 28% after OX treatment. We further showed a 65% increase in the efficiency of protein synthesis with OX. In combination, this could lead to an accrual of lean body mass in the fed state.

Androgens induce their specific response via the AR, which, in turn, regulates the transcription of androgen-responsive target genes. Although we know that accumulation of DNA is essential for muscle growth, the mechanisms of androgen-induced DNA accretion in skeletal muscle are unclear. AR (23) and AR mRNA (24) have been detected in human skeletal muscle. However, to date there are no human studies that have examined the response of skeletal muscle ARs to androgen exposure. Moreover, it has been suggested that prior cellular exposure to androgens may somehow prime these cells for the action of secondary agents such as IGF-I. Therefore, a secondary objective of this study was to examine the effect of OX administration on mRNA concentrations of IGF-I and ARs.

A recent study in exercising rats indicates that the accretion of skeletal muscle may be dependent on an increased number of ARs (25). Inoue *et al.* (25) examined the physiological importance of the increase in ARs on exercise-induced muscle hypertrophy. They determined that the androgen pathway had a significant effect on exercise-induced muscle hypertrophy and found the hypertrophy to be associated

with an increased number of ARs in the exercised muscle (25). Moreover, a study conducted by Doumit *et al.* (26) found that pretreatment of porcine satellite cells with T for 24 h up-regulated AR, but did not alter the responsiveness of these cells to IGF-I or other growth factors. Similarly, we found an increased expression of AR mRNA with no change in im IGF-I mRNA concentrations after a short term administration of OX. These data along with our findings of increased mRNA concentrations of ARs with short term exposure to OX lend support to the contention that ARs may regulate, either directly or indirectly, the accumulation of DNA required for muscle growth.

More recent evidence lends support to the complementary roles of androgens, ARs, and IGF-I. Urban *et al.* (5) found increased mRNA concentrations of IGF-I in skeletal muscle of elderly men given 4 weeks of replacement doses of TE. Further, by inducing severe androgen deficiency in young men for 10 weeks, Mauras *et al.* (27) showed marked decreases in mRNA concentrations of IGF-I and suggested that within skeletal muscle tissue, androgens are necessary for local IGF-I production, independent of GH production and systemic IGF-I concentrations. In addition, new data from this study of androgen-deficient men indicate that ARs are significantly decreased in response to severe hypogonadism (28). Although there is no direct evidence that OX binds to the ARs, the findings of the present study and those reported by Hayes *et al.* (28) suggest that androgens may work directly through the androgen receptor to exert their effects on protein metabolism. Nevertheless, we do not know from the present study the physiological importance of the increased expression of mRNA for AR.

In summary, this study demonstrates that OX, administered once a day at a moderate dose (15 mg/day), promotes net muscle protein synthesis. Moreover, these data suggest that OX induced an increase in AR expression as a mechanism for the increase in net muscle protein synthesis.

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